TABLE 2.—*Comparisons of observed minimum temperatures with values forecast from computations from the radiation equation* $(T=D-\frac{H-25}{4}+V-V')$—Continued

SPRING SERIES—Continued

Date	Temperature, p. m.	Relative humidity p. m.	Dew point, p. m.	Forecast bog minimum	Actual bog minimum	Error
1923	°F.	Per cent	°F.	°F.	°F.	°F.
May 1- 2	63	37	36	31.0	28.0	+3.0
2- 3	59	52	41	30.3	32.2	−1.9
3- 4	60	50	41	30.8	30.2	+0.6
4- 5	69	50	50	35.8	35.2	+0.6
6- 7	62	62	48	33.8	33.0	+0.8
10-11	53	50	34	27.8	23.4	+4.4
13-14	65	56	49	34.3	32.0	+2.3
14-15	61	35	33	29.8	31.5	−1.7
22-23	68	50	49	34.8	34.5	+0.3
23-24	65	48	45	33.3	28.5	+4.8
24-25	60	34	32	29.8	30.0	−0.2
25-26	76	38	48	36.8	37.6	−0.8
26-27	80	41	54	40.0	40.3	−0.3
27-28	66	59	51	34.5	36.5	−2.0
31-June 1	62	81	56	35.0	33.1	+1.9
June 9-10	68	76	60	37.3	35.5	+1.8
10-11	75	66	63	38.8	41.1	−2.3
29-30	72	85	68	39.0	37.0	+2.0

Average error, −0.4°.

FALL SERIES

1921						
Sept. 22-23	81	79	57	36.5	42.0	−5.5
23-24	82	80	59	37.3	31.5	+5.8
24-25	76	93	52	32.0	40.0	−8.0
25-26	81	91	68	40.5	38.0	+2.5
26-27	74	92	47	28.3	29.8	−1.5
30-Oct. 1	86	92	55	34.3	29.0	+5.3
Oct. 1- 2	69	84	45	28.3	29.3	−1.0
3- 4	65	94	61	35.8	34.0	+1.8
4- 5	64	85	40	25.0	29.4	−4.4
6- 7	70	76	45	28.3	29.8	−1.5
8- 9	48	80	38	23.3	22.0	+1.3
9-10	60	87	38	23.5	29.0	−5.5
10-11	76	83	52	33.5	32.0	+1.5
12-13	56	77	37	24.0	22.0	+2.0
13-14	54	89	32	20.0	18.9	+1.1
14-15	70	96	39	22.3	21.4	+0.9
1922						
Sept. 22-23	60	72	51	33.3	36.2	−2.9
25-26	54	54	37	24.8	25.0	−0.2
26-27	52	78	45	28.8	28.1	+0.7
27-28	61	89	58	36.0	38.7	−2.7
Oct. 12-13	53	52	36	23.3	29.5	−6.2
13-14	52	62	39	24.8	27.1	−2.3
17-18	64	59	50	33.5	31.0	+2.5
18-19	50	48	30	22.3	20.0	+2.3
19-20	40	68	30	21.3	24.0	−2.7
24-25	34	81	29	20.0	22.5	−2.5
26-27	40	53	26	19.0	16.5	+2.5
1923						
Sept. 10-11	64	70	54	34.8	34.5	+0.3
11-12	64	82	58	36.8	39.5	−2.7
14-15	52	63	40	26.5	27.5	−1.0
15-16	54	73	45	29.0	29.5	−0.5
16-17	54	59	40	26.5	26.0	+0.5
17-18	55	65	43	28.0	28.0	±0.0
29-30	70	72	61	38.3	36.0	+2.3
Oct. 1- 2	56	65	44	28.0	31.0	−3.0
2- 3	61	65	49	32.0	34.0	−2.0
3- 4	56	65	44	28.0	33.0	−5.0
4- 5	65	52	47	30.3	22.5	+7.8
5- 6	45	78	38	23.8	24.0	−0.2
6- 7	44	78	37	23.8	15.5	+8.3
7- 8	45	86	41	24.8	20.3	+4.5
8- 9	47	69	37	24.0	20.0	+4.0
9-10	46	77	38	24.0	23.0	+1.0

Average error, −0.6°.

WEATHER DURING APRIL 21–26, 1924, AND THE FREE-BALLOON FLIGHTS OF APRIL 23–25

By V. E. JAKL, Meteorologist

[Weather Bureau, Washington, May 24, 1924]

The sequence of weather conditions over the country during the period of April 21–26, of more than passing interest in themselves, is of additional interest in view of the free-balloon flights of April 23–25, and their meteorological significance. An account of the national balloon race of 1924 and of the participation of the Weather Bureau in furnishing the pilots with all possible information before and during the flights, is given in the following extract from the report of Mr. J. H. Jarboe, official in charge of the Weather Bureau station at San Antonio, Tex.:

Seven balloons started from San Antonio, Tex., during the late afternoon of April 23, 1924, competing for distance in the national elimination balloon race. No records were broken, but four balloons exceeded a thousand miles, and the average mileage for the seven contestants was 798. The general course taken by all balloons was somewhat east of north, and closely coincided with the surface isobars, but the rapid and continuous movement of the balloons northward was quite unusual. Thunderstorms were encountered by all pilots as the balloons neared the center of low pressure, the first balloon being forced down 16 hours 46 minutes after the start.

Six of the balloons were equipped with radio sets, and the pilots received weather forecasts during their flight. Their logs show that messages came in from numbers of stations, some reaching as far eastward as New York the first night.

A rather comprehensive schedule for supplying meteorological information was conducted. Weather maps, forecasts, and upper-air conditions from Weather Bureau and Army aerological stations were supplied in bulletin form, and pilot-balloon runs were made hourly at the field by the Army meteorological detachment. The contestants were well informed of current and expected weather development before leaving the ground, and ample provision was made for supplying this information by radiophone during the race. Pilots were keenly interested in this feature, taking with them weather maps, forecasts, reported wind velocity aloft, and a schedule of broadcasting stations. The distance covered, time in the air, and the approximate location of the place landed are shown herewith:

Pilot	Duration			Miles	Landed (near)
	H.	M.	S.		
Van Orman	44	4	44.6	1,072	Rochester, Minn.
Honeywell	39	11	0	1,042	Sanborn, Minn.
Peek	32	27	15	1,021	St. Ansgar, Iowa.
Thaden	34	8	26.2	1,003	Dubuque, Iowa.
Hill	25	20	20	565	Moline, Kans.
Fournier	18	7	32	517	Kaw City, Okla.
McKinley	16	46	0	365	Wapanucka, Okla.

The balloons started off with a surface wind of 12 to 14 miles per hour from the southeast. They traveled at altitudes of 200 to 400 meters, but increased their altitudes during the night and were soon making 30 to 35 miles an hour. Air currents at an altitude of 500 to 1,500 meters were used for the larger part of the race, the balloons traveling so rapidly at times that the pilots experienced difficulty estimating their positions.

Weather conditions and forecasts indicated that the balloons were being drawn into the center of the LOW while crossing Kansas, and altitudes up to and above 5,000 meters were used. Snow and freezing temperatures were encountered in the higher levels, as well as physical discomfort due to altitude. On the morning of April 25 four balloons were still in the air above northern Iowa and southern Minnesota, with the center of the LOW south of them. Thunderstorms and adverse winds on this date brought the race to a close, and the victory to W. T. Van Orman.

The week opened with an elongated LOW central over Missouri, attended by precipitation over its northern portion. This LOW was displaced the following morning (22d) by a weak HIGH, the LOW meanwhile passing off northeastward with increasing area of precipitation. By the morning of the 23d, the HIGH had increased in extent and depth and was overlying practically all the eastern half of the country. Coincidently with the development of this HIGH, scattered areas of low pressure in the west later merged into a well-marked trough that covered the western half of the country by the morning of the 23d, the major axis of the trough extending about NE. to SW. over the plateau region.

This distribution of pressure on the 23d indicated general south to north movement of air over middle sections of the country, the low and high areas being separated by approximately straight isobars extending from the Gulf to Canada. Wind conditions were therefore favorable for distance flights from San Antonio, as, following the gradient winds at moderate altitudes, the

balloons would necessarily drift in a general northerly direction. From the evidence of aerological observations, no other course gave as good promise of attaining distance from the starting point. The winds observed at about the time the balloons took off were steady southerly, becoming southwesterly at 2,000 meters, from Texas north to North Dakota. Velocities in the southerly current averaged about 30 miles an hour, being highest about 1,000 meters above the ground, and higher over northern sections than in the south. Over the Mississippi Valley and sections to the east the winds were lighter and more variable in direction, with a tendency to westerly in the higher altitudes. Over the Atlantic States the winds aloft had mostly a northerly component.

The same general drift prevailed on the 24th, except that the winds were south to higher altitudes over the eastern portion of the Plains States, and steadier and stronger south in the lower altitudes over the Mississippi Valley, the western trough of low pressure having developed in intensity and advanced farther east during the preceding 24 hours. Over the Eastern States no strong winds of definite general direction were observed except over the lower Lake region and thence eastward, where strong westerly winds were reported above about 1,000 meters. However, these westerly winds were not accessible to the pilots, as the southerly drift had carried the balloons only as far north as the lower Missouri Valley by the evening of the 24th. During the night of the 24-25th, the balloons that were still in the air made fairly good progress over Iowa, two penetrating into Minnesota by the morning of the 25th.

The wind conditions, substantially as outlined, were radioed to the pilots during the progress of the race in a series of bulletins given to broadcast stations that were successively within easy range of the balloons. Successful reception of these messages is attested to by the experience of Mr. W. T. Van Orman, the winner of the race, from whose report the following remarks are quoted:

> The stations from which our balloon, the *Goodyear Third*, received reports are as follows: WOAI, San Antonio; WBAP, Fort Worth; WMC, Memphis; KSD, St. Louis, KDKA, Pittsburgh. These reports were extremely valuable to us in our flight. You might be interested to know that in addition to these stations we arranged with and received weather reports from the following stations (naming 11 other stations) * * * We are inclosing a sample of the report which we requested these stations to broadcast, and in the majority of cases we found that their reports came out in this form.
>
> It is our opinion that the distance made in this recent race was made possible to a very large degree through the cooperation of the Weather Bureau and the various broadcasting stations. In conclusion, I might say it would be well in all subsequent races to arrange for broadcasting of the reports on a very much broader scale, as their value has been definitely proven in this contest. Please accept my most sincere thanks for the cooperation of the Weather Bureau given us in the recent contest.

Sporadic thunderstorms on the front of the trough over Oklahoma and Kansas forced some of the balloons down on the 24th, the remainder having been able to continue in the air until they reached Iowa and southern Minnesota on the morning of the 25th. Further progress was impossible, as by this time showers and thunderstorms were of general occurrence or impending throughout the upper Mississippi Valley and western Lake region. It is to the credit of the intrepid pilots and their aids that they were able to attain the distances they did in view of the threatening weather conditions they had to contend with on the 24th and 25th. The winner of the race lacked only about 100 miles of equaling the American record for distance. The paths followed by the two leaders in the balloon race and that of the Army balloon are shown in Figure 1.

Simultaneously with the start of the national balloon race an Army balloon, Lieut. James T. Neely, pilot, carrying C. Le Roy Meisinger, of the Weather Bureau, as meteorological observer, took off independently from Scott Field, Belleville, Ill., in one of a series of constant-elevation flights. This balloon, after drifting northward about 400 miles, was compelled to land in Wisconsin on the morning of the 24th for reasons similar to those that ended the balloon race in Iowa and Minnesota on the 25th. Threatening weather and variable winds developed in the night of the 23d–24th in the northeastern sector of the low-pressure trough, which on the morning of the 24th extended from Arizona and New Mexico northeastward to the Dakotas and Minnesota. Over this sector the observed easterly winds in the lower levels evidently became southwesterly at higher altitudes, as observations on the 24th and 25th within the low-pressure area indicated a wind structure characteristic of troughs, i. e., winds aloft of southerly component extending well beyond the rear and north of the center.[1] Observations at Ellendale and Denver on the 24th showed south to southwest winds aloft to 5,000 meters above winds in the lower levels that were northeast and west, respectively, and at Madison strong southwesterly winds aloft above surface winds that were becoming easterly. Drexel, on the 25th, showed a north surface wind, changing at about 300 meters altitude to south and southeast winds that extended to over 3,000 meters altitude.

In the lower levels over the region of Wisconsin and Minnesota the transition from southerly to easterly winds apparently occurred within a small latitudinal distance, the Army balloon having been carried in the last laps of its journey on the 24th in an arc of short radius (approximately shown in Fig. 1) from a southwest to an easterly wind. This is also well indicated in the opposing surface wind directions in the northeastern sector of the trough shown on the weather maps of the 24th and 25th. Reproductions of the weather maps showing the pressure distribution near the beginning and ending of the balloon race and at the time of landing of the Army balloon are given in Figures 1 to 3.

Following up the development of this low-pressure trough it will be noted that on the 26th the main center was over Iowa, with major axis trending NW. to SE. and general precipitation during the preceding 24 hours reported within its confines. A LOW with a NW. to SE. orientation of major axis, while of frequent occurrence,[2] is nevertheless abnormal, inasmuch as usually the trend of a trough of low pressure tends to become NE. to SW.[3] A closer study is therefore suggested of the general antecedent conditions, already briefly outlined in the earlier part of this paper. It will be noted that the HIGH, first faintly evident over the upper Missouri Valley on the p. m. map of the 21st, had evidently been gradually reinforced from the north. After it had attained its maximum depth and extent over the Eastern States on the 23d, another HIGH appeared, approaching from Ontario, which continued to develop and advance southward until on the 26th it was dominant over northeastern sections of the country, with highest pressure still over Ontario. Concurrently, pressure rose over the Pacific to a maximum on the 23d, followed by a decline on the 26th, and a rise in pressure over the Canadian mainland (see Northern Hemisphere map, not reproduced). An accompaniment of this pressure cycle was the advance south-

[1] See footnote 10, MO. WEATHER REV., January, 1924, 52:21.
[2] Of numerous examples, the weather maps of Apr. 28, 1918, Apr. 21, 1923, and Apr. 17, 1924, show well-defined types.
[3] See footnote 2, MO. WEATHER REV., February, 1924, 52:101.

eastward of an area of high pressure and lower temperature over the Rocky Mountain States on the 24th–26th, which, occurring simultaneously with the development of the Ontario HIGH, had the effect of segregating the northern portion of the low-pressure into the configuration observed on the 26th.

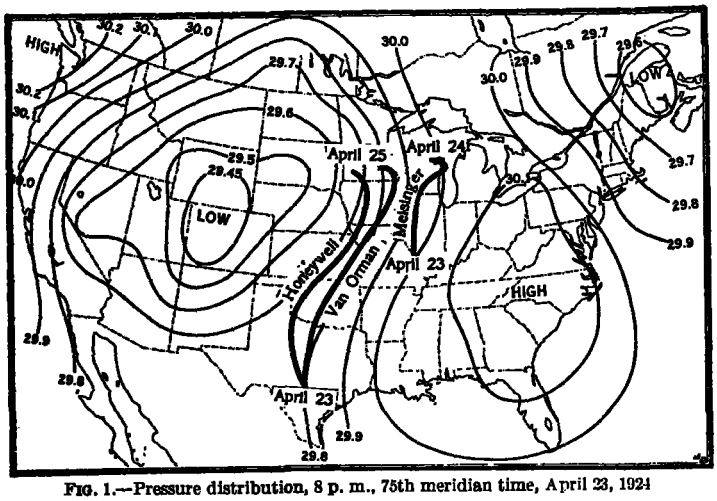

FIG. 1.—Pressure distribution, 8 p. m., 75th meridian time, April 23, 1924

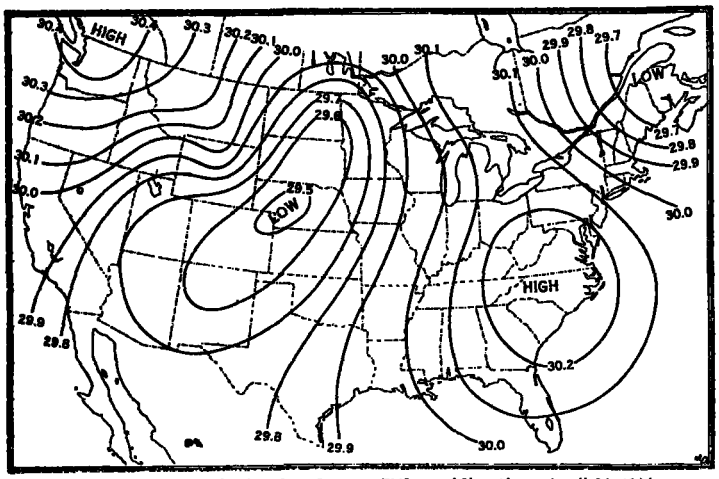

FIG. 2.—Pressure distribution, 8 a. m., 75th meridian time, April 24, 1924

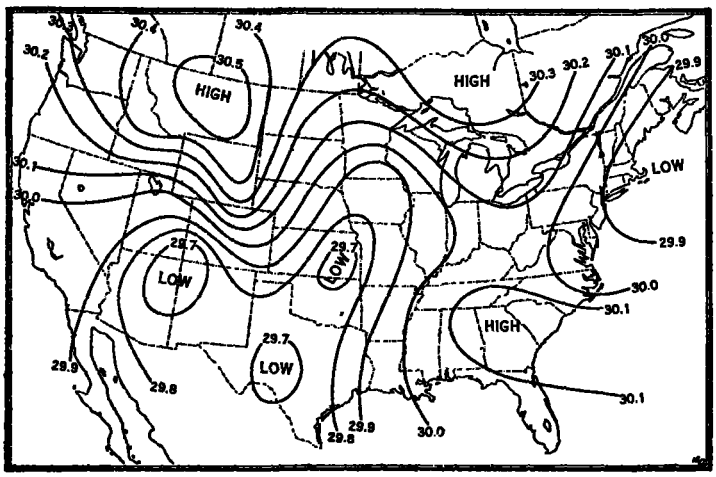

FIG. 3.—Pressure distribution, 8 a. m., 75th meridian time, April 25, 1924

An observation of SSE. wind aloft at 4,000 meters over Drexel on the 25th and at 4,500 meters over Ellendale on the 27th leads to the inference that a normal west-to-east movement of the detached LOW was prevented by the persistency of the Ontario HIGH, of which the SSE. winds aloft were a consequence. A close examination of the isobars on the weather maps from p. m. of the 24th to p. m. of the 26th shows that there was a retardation of the northern limb of the low-pressure trough in the region of the Dakotas and Minnesota during this period that amounted actually to a slight retrogression on the 26th. Further confirmation of this is given by the surface-wind record at Ellendale, where the wind changed from southerly to northerly on the 24th, and veered back to southeasterly on the 26th. It is noteworthy that precipitation did not occur at Ellendale until the wind veered from northwest to directions ranging from north through east to southeast, and that at Drexel precipitation was delayed nearly 20 hours after the wind had changed from south to northwest, and about 8 hours after it had begun at Ellendale. The significance of this is that the precipitation that occurred in the rear of the trough on the 25th and 26th can not all be attributed to the under-running effect of the cold high-pressure area from the northwest. Over southern sections only was it plausibly due to this cause. Over most of the Dakotas and Nebraska it seems more reasonable, from the foregoing facts, that precipitation was due to processes connected with the transport of air from around in front of the LOW.[5] The distinction between the two types of precipitation is often evident by a gap in the shaded area in the rear of the LOW, as is apparent on the a. m. weather map of the 25th.

In connection with the precipitation that occurred east of the low-pressure area, it is interesting to note the changes in temperature that occurred with changing configuration of isobars and, consequently, sources of supply of air. On the 24th at Drexel the temperature was 14.1° C. at 2,000 meters in a SSW. wind; and at Ellendale 15.2° C. at 2,000 meters in a southeast wind, and 6.8° C. at 3,000 meters in a south wind. At Royal Center the temperature was 7.2° C. at 2,000 meters in an east wind on the 26th; and on the 27th, 6.2° C. at 2,000 meters in a SSE. wind, and 1.0° C. at 3,000 meters in a southwest wind. The lower temperatures at Royal Center than at corresponding levels at stations to the west and northwest a few days previously were undoubtedly due to the difference in the source of air. On the 24th the air aloft over Drexel and Ellendale was supplied by the drainage extending far to the south and southwest, in paths approximating the course taken by the balloons. At Royal Center the winds in the lower levels on the 26th and 27th had their origin in the HIGH to the east, while the southwest wind observed at 3,000 meters on the 27th can be traced back in a curved path to the cold HIGH that appeared in the northwest on the 24th. Rain began at Royal Center on the 27th as soon as the wind near the ground changed from easterly to a more southerly component, indicating the building up of an adiabatic gradient between the warm southerly currents near the ground and the cold southwest wind aloft.[6]

551.55

NEW STANDARDS OF ANEMOMETRY

S. P. FERGUSSON and R. N. COVERT

With the approval of the Chief of the Weather Bureau, the authors, in 1921, began a redetermination of the rate of the standard anemometer extending to higher velocities than any attained in earlier tests of the instrument. This work was made possible by the generous cooperation of the aerodynamical laboratory of the Bureau of Standards in providing and operating the two wind tunnels in which

[5] MO. WEATHER REV., January, 1924, 52: 21 (par. (c)).
[6] MO. WEATHER REV., January, 1924, 52: 20 (3d par., 2d. column).